Monitoring water quality at the ground water table beneath areas of dairy manure application to assess manure management strategies, Whatcom County, Washington

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Problem —In many areas of Washington State where heavily impacted water resources are present and where agriculture and increasing population pressures are co-located; poorly managed agriculture (in particular, manure application) has repeatedly been advanced as a leading contributor to water pollution in the watersheds. The fate of nitrogen applied to soils in the form of dairy manures is a key environmental question and quantitative details of seasonal variability in the soil nitrogen budget beneath fields were application of liquid dairy manures to crop fields and effects on underlying groundwater quality is not well documented.

Within the Puget Sound region Whatcom County has the greatest concentration of dairy cows, with 53% of the total, or over 40,000 animals (2008), most (~75%) of which are concentrated in the 310 mi^2 of the Nooksack and Strait of Georgia watersheds. Since dairies are the largest producers of manure and manure application to farm fields is the primary use of manure in the watershed, improvements in field application strategies that increase crop uptake are expected to improve protection of important watershed and air resources from further negative impacts. Current regulations for application of manure relay primarily on the seasonal calendar and do not incorporate a thorough assessment of hydrologic conditions of the field site or crop growth requirements. This seasonal based management strategy has resulted in instances of manure applications occurring during approved application periods but when environmental and hydrologic conditions were prone to result in degradation of water resources. In addition there is the potential loss of manure application opportunities during favorable conditions on fields which have unique hydrologic conditions, which maybe suitable for manure application at times when manure applications are currently precluded due to regulatory constraints. Refinements to manure application strategies could reduce potential for off-site resource degradation.

The Whatcom Conservation District has initiated a study to develop and test an alternate and innovative strategy for identifying appropriate conditions for scheduling manure application to fields based on an analysis of field hydrologic properties (U.S. Dept. of Agriculture 1992), crop growth requirements, and environmental conditions. The innovative manure management strategy being evaluated, Application Risk Management (ARM) system, will evaluate runoff, leaching, and volatilization potential to help farmers reduce their risk of manure induced pollution. A comparison of effectiveness of resources protection to off-site migration of nutrient and fecal bacteria from the two manure management strategies will be tested in a field study using pair test plots. As initially

planned for this study, off site migration of nutrients and bacteria to groundwater would be monitored as the flux from the root zone from each test plot measured through a network of sub-root zone lysimitors. However, water movement and water-quality measurement within the unsaturated zone are typically quite variable due to the very heterogeneous nature of soils and soil microbial community. The addition of a groundwater element to the study design of the ARM system in which measurements of water quality concentrations at and near the water table surface would provide broader more-integrated information regarding the transport of nutrients and bacteria to the groundwater system and that will significantly augment study results.

Objectives — The objective of this study is to collect and evaluate groundwater chemistry data in support of the ongoing ARM study being conducted by Whatcom County Conservation District. This objective was not part of the initial ARM study design but is needed to fully evaluate differences in manure management strategies as they relate to impacts to water resources. The data will reduce uncertainty related to potential impacts to the groundwater system and will provide a key component to overall utility of study results and increased the level of confidence in overall study results.

Relevance and Benefits — The study will monitor transport of potentially hazardous nutrients and bacteria. The study is consistent with the USGS strategic science direction "A National hazards, risk, and resilience assessment program," "Climate variability and change," and "Understanding Ecosystems and Predicting Ecosystem Change: Ensuring the Nation's Economic and Environmental Future" identified in the 2007-17 science strategy of the USGS (U.S. Geological Survey, 2007). The USGS is able to receive interagency funds USEPA for water resources investigation under statute 43 USC 50-1

Approach –The focus of this study will be on monitoring the changing concentrations of nutrients and fecal bacteria in groundwater at and near the water table beneath study plots at various times during the agricultural and dormant season. The governing assumption is that the water quality at the water table is most affected by the downward movement of recent recharge through the unsaturated zone. Monitoring at the water table will necessitate a flexible sample collection approach able to isolate the uppermost 6 inches of the saturated zone in a ground water system in which fluctuate seasonally fluctuation of the water table can be as much as 10 feet (Cox and Kahle 1999). An additional complicating requirement will be the collection of multiple samples (2-4 per field plot) sufficient to assess near scale variation in water quality concentrations resulting from hydrogeologic heterogeneity so that differences from contrasting manure management strategies can be distinguished temporal and plot-scale variability.

The following tasks will be included:

Task 1(A) QAPP The USGS will prepare a Quality Assurance Project Plan specific for this project and based on project requirements and existing USGS quality assurance documents (Wagner and other 2007) and USEPA guidance documents. The QAPP will provide detail information on sample collection methods, analyte list and analysis methodology, quality assurance procedures that will be used to ensure that data are collected of known quality including analysis of bias and variability.

Task 1.(B) Interagency Coordination The USGS will coordinate the sampling and analysis plan (SAP) for this study with the SAP developed by WCD so that the two studies, though funded separately, will be yield a combined study data set with sufficient quality assurance measures that the data will be fully comparable and able to be combined. The USGS and WCD will collaborate on screening and selection of test sites which will be critical to the successful integration of the study design. Communication linkages will be established between USGS and WCD to facilitate collaboration, data sharing, coordination of sampling events, and execution of project tasks.

Task 2.(A) Monitoring Well Installation In 2011 and 2012 the USGS will install 2 to 4 monitoring wells in each of the paired 10 acres farm plots located at 6 diaries. Additional wells will be installed in 2013 and 2014 if project funding continues. All of the sites selected will be made in consultation with WCD to provide data that is most useful to test comparison of manure management strategy. Candidate sites include plots on slity, sandy, and gravelly loam. All wells will be located within the manure management test areas but away from the boundary margins to eliminate influences from outside the test area. Half of the groundwater wells installed near or at WCD lysimeter sites. The influence of nearby pump wells, particularly irrigation wells and other localized feature that will affect the local groundwater flow system will be considered in locating well installation sites. The location and elevation of monitoring well be surveyed to establish vertical datum to within 0.1 ft resolution of project datum. Water level recording devices will be installed in at least 3 wells on each farm site to provide continuous water-level data. All well and construction information, water-level data, and water quality data will ultimately be stored in the USGS National Water Information System (NWIS) database.

Task 2. (B) Refining Sampling Protocol USGS will test and document water quality sampling methods to find those that can best characterize water quality in the uppermost 6 inches of this system where the position of the water table may seasonally vary by as much as 10 feet. The adopted sampling method(s) will isolate the upper 6 inches of the water column within the well and extract groundwater at the rate that will not significantly aerate the water sample. A multi-level sampling device, consisting of either a variable –zone packer system or passive-diffusion sampler, will be used to measure the vertical variation of nutrient concentrations in ground water at and just below the groundwater table. The adopted sampling method must also be suitable for collection of microbiolgical samples.

Task 3. Collect Monitoring Data: Collect and analyze water-quality samples and groundwater level data to document temporal and local spatial variability in the nutrient content of recent recharge. Chemical analysis of water samples will include nutrients, selected redox indicators, and selected common ions such as potassium and chloride which are correlated to dairy manures. Within each study plot (two plots per site) two to three multi-level sampling well systems will be installed along the central

groundwater flow line. Measured water-quality profiles within the upper 3 feet of the saturated system will obtained using multi-level discrete sampling devices. During the seasonal recharge period of the year, sampling interval will be more frequent to capture accumulated input from summer growing season and selected high intensity recharge events. During drier periods, monitoring data collected at less frequent intervals of 3 to 6 weeks intervals. Analysis of variance will be used to distinguish localized variations and to compare between manure management strategies.

Task 4. Data management and analysis: Laboratory and field data will be review for quality assurance purposes and stored in the National Water Information System NWIS database. Water-quality data from the water table will be evaluated with respect to manure application, irrigation, and weather data collected by WCD to assess rate of vadose zone transport. The chemical profile in the upper 3 feet of the saturated zone will used to monitor mass of nutrients in groundwater near the water table. Analysis of the data will include estimates of the nutrient flux to groundwater from each of the manure management strategies. Comparison the nutrient flux estimated will be made using non-parametric statistics.

Task 5. Interagency technical consultation with researchers from EPA, WCD, and WDOE will continue through the duration of the project. In late spring of 2012, results from the first winters sampling efforts will be shared informally prior to initiation of 2012 sampling season.

Task 6. Report —The results of the groundwater quality data collection will be released in multiple documents and products. A year-one progress report with provisional results will be presented as a slide presentation to EPA and interested stakeholders in ***September 2012***. A draft manuscript of the final study report will be made available to EPA for internal review by ***September 30, 2014***. The final report will be produced as a USGS-approved draft manuscript for submission to a peer-reviewed scientific journal or published as an online-only USGS-series report by ***December 31, 2014***.

Timelines—The project will begin July 2011 and be completed December 2014.

Calendar Year	2011	2012					2013						2014			
Federal Fiscal Year	###	**2012**					2013						2014			
FFY Quarter	Q4	Q1	Q2		Q3	Q4	Q1		Q2		Q3	Q4	Q1	Q2	Q3	Q4
Tasks																
Task 1A. Prepare Quality Assurance Project Plan	x															
Task 1B. Project integration and coordiantion; (WCD site selection & sampling; WDOE multizone resource protection wells)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Task 2A. Install monitoring wells with vertical isolation sampling system, & WL recorder	x					x						x				
Task 2B. Develop and document sampling protocol to best represent qw characteristics w/in 15 cm of water table.	x															
Task 3. Collect and analyze water-quality samples (& W/L data) from wells to define temporal and local spatial variability	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Task 3. Integrate data analysis with data collected from soil zone.		x	x	x	x	x	x	x	x	x	x	x	x	x		
Task 4A. Analyze timing and rate of vadose zone transport of nutrients and colifoms to water table.					x	x					x	x		x	x	
Task 4B. Consultation and interagency collaboration USGS, WCD, EPA, WDOE	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Task 5A. Year one status report/update				x												
Task 5B. Prepare and publish USGS-series report or submit USGS-approved manuscript to scientific journal.															x	x

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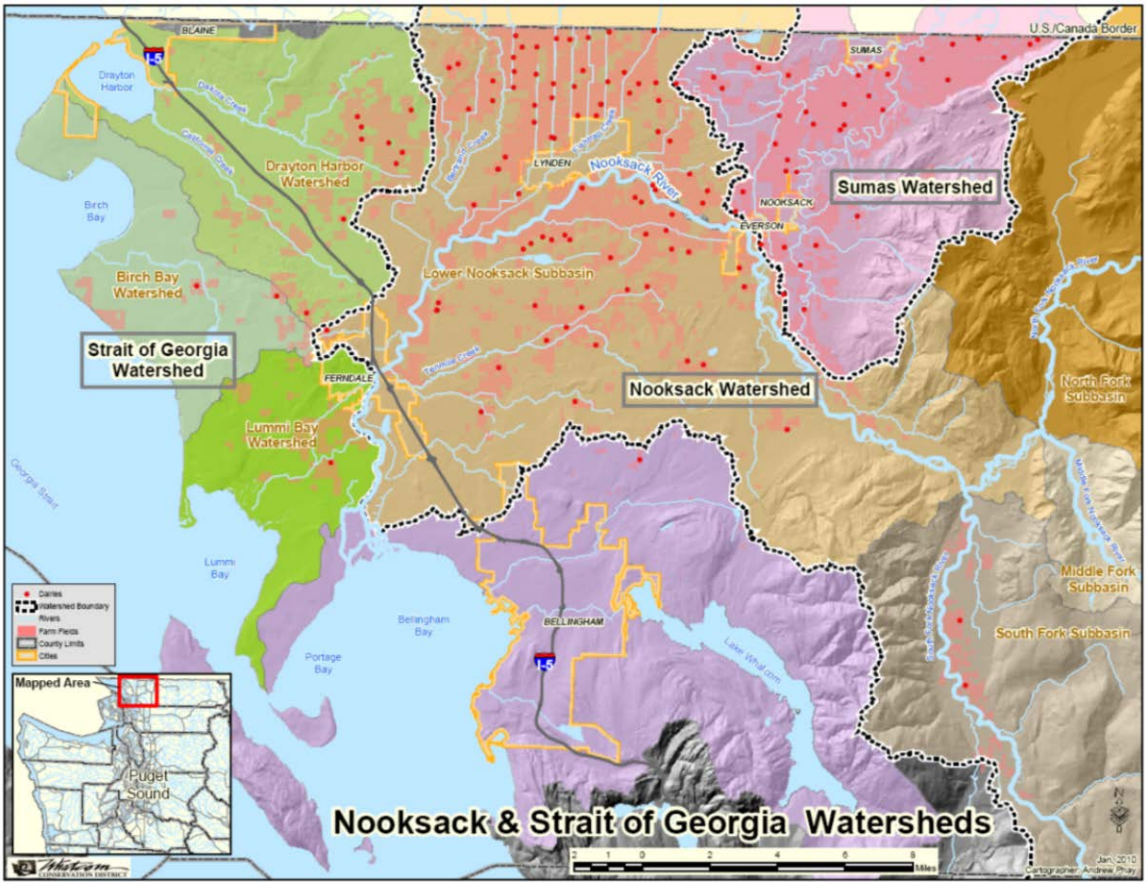

Figure 1. Map of the study area. Red dots depict dairies and pink area represent land base associated with those dairies. Whatcom County, Washington.

Budget— The total cost of the full version of the study with all tasks (i.e., tasks 1-5 listed above) is $775,000. (The study cost breakdown by federal fiscal year, shown below, assumes a starting date of October 2010).

Agency		**FY 2011 & 2012**	**FY2013**	**FY2014**	**TOTAL**
EPA		$288,400	$226,000	$251,000	$775,000
Total		$288,400	$226,000	$251,000	$775,000